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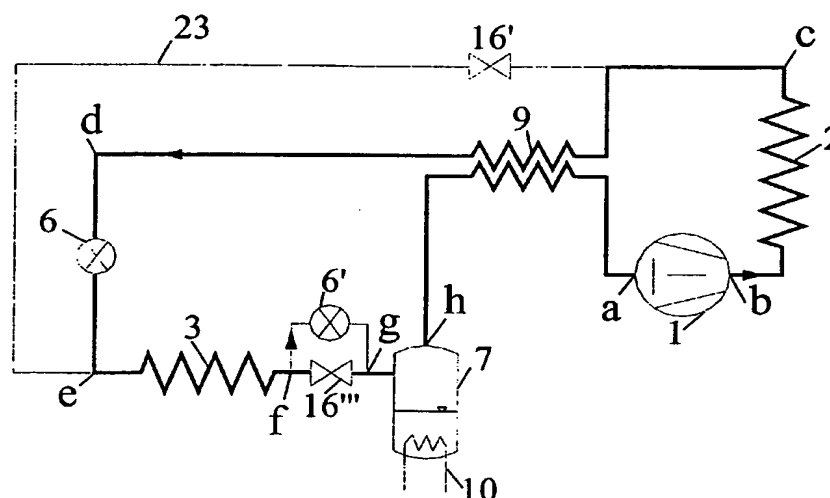
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(54) Title: METHOD AND ARRANGEMENT FOR DEFROSTING A VAPOR COMPRESSION SYSTEM



(57) Abstract: Method for defrosting of a heat exchanger (evaporator) in a vapor compression system including, beyond a heat exchanger (evaporator) (3) to be defrosted, at least a compressor (1), a second heat exchanger (condenser/heat rejecter) (2) and an expansion device (6) connected by conduits in an operable manner to form an integral closed circuit. The heat exchanger (3) to be defrosted is subjected to essentially the same pressure as the compressor's (1) discharge pressure whereby the heat exchanger (3) is defrosted as the high-pressure discharge gas from the compressor (1) flows through to the heat exchanger, giving off heat to the said heat exchanger (3). An arrangement is characterized in that, in the circuit, in connection with the expansion device (6) is provided a first bypass loop (23) with a first valve (16'), and that a pressure reducing device (6') is provided in a second bypass loop in conjunction with a second valve (16'') disposed after the heat exchanger (3) being defrosted, whereby the first valve (16') is open and the second valve (16'') is closed when defrosting takes place.

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Method and arrangement for defrosting av vapor compression system**Field of the invention**

The present invention relates to a method and arrangement for defrosting of the heat exchanger (evaporator) in a refrigeration or heat pump system including, beyond the first heat exchanger (evaporator), at least a compressor, a second heat exchanger (heat rejecter) and an expansion device connected by conduits in an operable manner to form an integral closed circuit.

Description of prior art

In some applications such as an air-source heat pump or air-cooler in a refrigeration system, frost will form on the heat absorbing heat exchanger (functioning as evaporator) when the surrounding temperature is near or below the freezing point of water. The heat exchanger heat transfer capability and resulting system performance will be reduced due to frost buildup. Therefore a defrosting means is required. The most common defrosting methods are electric and hot gas defrosting. The first method (electric defrosting) is simple but not efficient while the hot gas defrosting method is most suitable when the system has two or more evaporators. In both cases, for a heat pump system, an auxiliary heating system has to be activated in order to meet the heating demand during the defrosting cycle.

In this regard US patent No. 5.845.502 discloses a defrosting cycle where the pressure and temperature in the exterior heat exchanger is raised by a heating means for the refrigerant in an accumulator without reversing the heat pump. Although this system improves the interior thermal comfort by maintaining the heat pump in the heating mode, the defrosting process does still require that the heating means must be large enough in order to raise the suction pressure and corresponding saturation temperature to above freezing point of water (frost). This aspect might limit, for practical reasons, the type of heating means (energy sources) that can be used with this

defrosting method (radiator system). According to the said patent, the defrosting cycle is meant to work only with a reversible heat pump.

Yet another disadvantage of this known system is that the refrigerant temperature in the accumulator needs to be higher than 0 degrees centigrade and this may limit the effective temperature difference available for heat transfer to the accumulator.

Finally, another disadvantage of this system is that the refrigerant temperature in the heat exchanger to be defrosted will be relatively low, and the defrosting time will have to be long in order to melt the frost.

Summary of the invention

The present invention solves the disadvantages of the aforementioned systems by providing a new, improved, simple and effective method and arrangement for defrosting the evaporator of a refrigeration or heat pump system.

The method is characterized in that the heat exchanger to be defrosted is subjected to essentially the same pressure as the compressor's discharge pressure whereby the heat exchanger is defrosted as the high-pressure discharge gas from the compressor flows through to the heat exchanger giving off heat to the said heat exchanger as defined in the attached independent claim 1.

The arrangement is further characterized in that, in the circuit, in connection with the expansion device is provided a first bypass loop with a first valve, and that a pressure reducing device is provided in a second bypass loop in conjunction with a second valve disposed after the heat exchanger 3 being defrosted, whereby the first valve is open and the second valve is closed when defrosting takes place as defined in the attached independent claim 11.

Dependent claims 2 - 11 and 13 - 19 define advantageous embodiments of the invention.

Brief description of the drawings.

The invention is described in more detail by referring to the following figures:

Fig. 1 and Fig. 2 show schematic representations of the principle of defrosting cycle operation according to the present invention.

Fig. 3 and 4 show schematic representations of embodiments of the invention shown in Figs. 1 and 2.

Fig. 5 shows T-S diagram for the process using the defrosting method according to Fig. 1.

Fig. 6 shows comparison of heating process for CO₂ and R12 in temperature/entropy (T-S) diagram where the defrost process for R12 corresponds to the process according to US patent No. 5845502.

Fig. 7, Fig. 8, Fig 9 and Fig. 10 show schematic representations of defrosting cycle according to present invention applied to further different embodiments.

Fig 11 shows experimental results from running defrost cycle which corresponds to claim 4 of present invention.

Detailed description of the invention

The invention relates generally to refrigeration and heat pump systems, more specifically but not limited, operating under transcritical process, to defrost a frosted heat exchanger and in particular an evaporator, with any fluid as refrigerant, and in particular carbon dioxide.

The invention can be used with any refrigeration or heat pump system preferably having a pressure receiver/ accumulator. If necessary, the

invention can also eliminate cool interior draft during defrost cycle that is associated with conventional defrosting methods in heat pump systems. This is achieved by means of an external heat source such as electrical resistance or waste heat (for example from car radiator cooling system) or any other appropriate means that can be incorporated into the receiver/accumulator or connecting piping along the path of the refrigerant in the circuit. Heat can also be supplied from a storage unit. The invention can be used with both sub-critical and transcritical refrigeration and heat pump system with a receiver/accumulator. The present invention can also be implemented with refrigeration and heat pump systems having only one evaporator.

The method of defrosting cycle operation according to this invention that follows is described with reference to Figs. 1 and 2 which could be either a heat pump system or a refrigerating (cooling) system. The system includes a compressor 1, a heat exchanger to be defrosted 3, a heat exchanger 9, two expansion devices, a first 6 and a second 6', a second heat exchanger 2 (heat rejecter), valves 16' and 16'', a receiver/accumulator 7 and a heating device 10. The second expansion device 6' is provided in a bypass conduit loop relative to the valve 16'' disposed after the heat exchanger (evaporator) 3. The addition of heat by a heating device and the provision of the second expansion device 6' bypassing the valve 16'' and the valve 16' bypassing the first expansion device 6, represents the major novel feature of the invention and makes it possible to subject the heat exchanger 3 to defrosting by maintaining essentially the same pressure in the heat exchanger as the compressor's (1) discharge pressure, whereby the heat exchanger 3 is defrosted as the high-pressure discharge gas from the compressor 1 flows through to the heat exchanger giving off heat to the said heat exchanger 3. The heating device 10 adds heat to the refrigerant preferably via a receiver/accumulator 7 but the heat can also be alternatively or additionally added to the refrigerant anywhere in the system along the path of refrigerant during defrost cycle.

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The normal operation (Fig. 1):

Under normal operation, the second expansion device 6' which is provided in a bypass loop relative to the valve 16''' and valve 16'' which is provided in a bypass loop relative to the first expansion device 6 are closed while valve 16''' is open. It is also understood that the second expansion device 6' can be a capillary tube or similar device which technically speaking will not be "closed" but there will be practically no refrigerant flow during normal operation. The circulating refrigerant evaporates in the exterior heat exchanger 3. The refrigerant enters into the receiver/accumulator 7 before passing through the internal heat exchanger 9 where it is superheated. The superheated refrigerant vapor is drawn off by the compressor 1. The pressure and temperature of the vapor is then increased by the compressor 1 before it enters the second heat exchanger (heat rejecter) 2. Depending on the pressure, the refrigerant vapor is either condensed (at sub-critical pressure) or cooled (at supercritical pressure) by rejecting heat. The high-pressure refrigerant then passes through internal heat exchanger 9 before its pressure is reduced by the expansion device 6 to the evaporation pressure, completing the cycle.

Defrost cycle:

With reference to Fig. 1, upon commencing of defrost cycle, valve 16' will be open and valve 16''' will be closed. According to this invention, the second heat exchanger (heat rejecter) 2 and the first heat exchanger (evaporator) 3 will be coupled in series or parallel and experience, as stated above, almost the same pressure as the discharge pressure of the compressor. The heat exchanger 2 can also be bypassed if necessary. This can be the case in refrigeration systems where there is no need for heat rejection by the said heat exchanger during the defrosting cycle. (Fig. 2)

The temperature and pressure of the refrigerant vapor is raised by the compressor 1 before it enters the heat exchanger 2. In case of heat pump operation where there is a need for heat delivery during defrost cycle, the refrigerant vapor) is cooled by giving off heat to the heat sink (interior air in case of air system). The high-pressure refrigerant can pass through the internal heat exchanger 9 or can be alternatively bypassed (as shown in Fig 1), before it enters the heat exchanger (evaporator) 3, that is to be defrosted, through the valve 16'. The cooled refrigerant at the outlet of the heat exchanger 3 then passes through the expansion valve 6' by which its pressure is reduced to the pressure in the receiver/accumulator 7. Heat is preferably added to the refrigerant in the receiver/accumulator 7 to evaporate the liquid refrigerant that enters the receiver/accumulator 7.

The type of application and its requirements determine the type of heating device and amount of heat needed in order to carry out the defrosting process. For example, using a compressor with suction gas cooled motor, the heat given off by the motor and/or heat of compression can be used as the "heat source" in order to add heat to the refrigerant during the defrosting cycle with minimum amount of energy input. Fig 14 shows some experimental results using a suction gas cooled compressor where heat of compression and heat given off by the compressor motor was used as "heat source". Or in case of a water heater heat pump system, the heat accumulated in the water in heat rejector and/or the hot water storage tank can be used as "heat source".

Using supercritical heat rejection pressure, there is an additional "degree of freedom" which adds further flexibility to this invention. While in a sub-critical system the pressure (and saturation temperature) in the condenser, heat exchanger 2 is automatically decided by the balance of the heat transfer process in said heat exchanger (heat rejector), the supercritical pressure can be actively controlled to optimize process and heat transfer performance.

Fig. 4 shows a further embodiment of the invention where the heat exchangers 2 and 3 are coupled in parallel by means of a 3-way valve 22 where, depending on the wanted speed of defrosting and heating effectiveness, part of the refrigerant from the compressor is led to the heat exchanger 3 through a bypass loop 22. Refrigerant led from the heat exchanger 2 is, in this example, bypassing the heat exchanger 3 by opening the valve 16" in a second bypass loop.

Further, Fig. 5 shows another embodiment where a 3-way valve 22 is used to bypass, partly or wholly the heat exchanger 2 (heat rejecter) through another conduit loop 21. This embodiment is useful in situations where speedy defrosting is wanted.

According to the invention; the supercritical pressure can be actively controlled to increase the temperature and specific enthalpy of the refrigerant after the compressor 1 during defrosting cycle which is shown in Fig. 5. The higher refrigerant specific enthalpy after the compressor 1 (point b in the diagram) is the result of increased work of compression when the discharge pressure is increased. In this respect, the possibility to increase the work of compression can be regarded as a "reserve heating device" for the defrosting method. As an example, this feature of the invention can be useful to meet the interior thermal comfort requirement, in a heat pump system, during defrost cycle with high heating demand. It is also possible to perform defrosting with running the second heat exchanger (condenser) 2 and first heat exchanger to be defrosted (evaporator) 3 in parallel instead of series during the defrost cycle.

The increased defrosting effect (specific enthalpy due to increased work) of the invention compared to the solution shown in for instance US patent No. 5.845.502 is further shown in Fig. 7. The diagram on the right hand side represents the process of the invention, while the diagram on the left hand side represents the process of the US patent. As can be clearly seen the defrost temperature is much higher with the present invention.

In applications other than heat pump or heat recovery systems, the main objective is to complete the defrost cycle as fast and efficiently as possible. In these cases, the heat exchanger 2 (heat rejecter), can be bypassed during defrost cycle as illustrated in Fig. 2 where a bypass conduit loop with a valve 16 is provided and which in such case is open. The defrost cycle can therefore be carried out faster than in the previous case.

Likewise the internal heat exchanger 9 may be bypassed by means of a conduit loop with valve 16' as is shown in Fig. 1.

The invention as defined in the attached claims is not limited to the embodiments described above. Thus according to the invention, the defrost cycle can be used with any refrigeration and heat pump system having a receiver/accumulator. This is illustrated in Figs. 7 - 9 where the same defrost cycle is implemented in different embodiments where for example flow reversing devices 4 respectively 5 are provided in sub-process circuits A and B to accomplish rapid change from heat pump to cooling mode operation.

Fig 10 illustrates the basic defrosting principle, according to present invention, when an intermediate pressure receiver is used. The said figure illustrates a defrosting cycle for a system where there is no need for heat rejection by the heat exchanger 2 during the defrosting cycle and where heat of compression is used as heating device. During the defrosting cycle, valves 16' and 16" will be open whereas valve 16''' will be closed. As a result, the high-pressure and temperature gas from the compressor passes through the valve 16' before it enters the heat exchanger 3 which is to be defrosted. The pressure of the cooled refrigerant is then reduced by expansion device valve 6''' to the pressure in the intermediate pressure-receiver 7. Since the said receiver is now in direct communication with the suction side of the compressor through a bypass loop which provides the valve 16'', the pressure in the said receiver will basically be the same as the compressor's suction pressure. Heat of compression is added to the refrigerant as the suction gas is compressed by the compressor to higher pressure and temperature. Since there is no

external heating device present in the system, the suction pressure of the compressor and that of the pressure receiver 7 will decrease until it will find an equilibrium pressure.

Claims

1. Method for defrosting of a heat exchanger (evaporator) in a vapor compression system including, beyond a heat exchanger (evaporator) (3) to be defrosted, at least a compressor (1), a second heat exchanger (heat rejecter) (2) and an expansion device (6) connected by conduits in an operable manner to form an integral closed circuit ,
c h a r a c t e r i z e d in that the heat exchanger (3) to be defrosted is subjected to essentially the same pressure as the compressor's (1) discharge pressure whereby the heat exchanger (3) is defrosted as the high-pressure discharge gas from the compressor (1) flows through to the heat exchanger, giving off heat to the said heat exchanger (3).
2. Method according to claim 1,
c h a r a c t e r i z e d in that, heat is added by a heating device (10) to the refrigerant in a pressure receiver/accumulator (7) or anywhere along the path of refrigerant.
3. Method according to claim 1,
c h a r a c t e r i z e d in that, the heat of compression from the compressor work and/or heat from compressor motor is used as heating device during defrost cycle.
4. Method according to claim 1,
c h a r a c t e r i z e d in that, the heat accumulated in the heat rejector, and/or an storage tank and/or other part of the system act as heating device during defrost cycle.

5. Method according to claim 1-4,
characterized in that, during the defrost cycle, the two heat exchangers (2 and 3) are coupled in series, and in that the high-pressure discharge gas from the compressor first flows through the first heat exchanger (heat rejector) (2), giving off some heat, before flowing through the second heat exchanger (3) defrosting said heat exchanger.
6. Method according to claim 1-4,
characterized in that, during the defrost cycle, the two heat exchangers (2 and 3) are coupled in parallel, and that the high-pressure discharge gas from the compressor is flowing through and heat is given off to both heat exchangers simultaneously in a controllable manner.
7. Method according to claims 1-6,
characterized in that the refrigeration or heat pump cycle is trans-critical.
8. Method according to claims 1- 7,
characterized in that the refrigerant is Carbon Dioxide (CO₂).
9. Method according to claims 1- 8,
characterized in that the defrosting process is trans-critical.
10. Method according to claims 1 - 8,
characterized in that the discharge pressure of the compressor (1) is actively controlled in order to change (increase or decrease) the temperature and specific enthalpy of the refrigerant at the outlet of the said compressor during the defrost cycle.

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11. Method according to the previous claims 1 - 10,
characterized in that the refrigerant is led to a pressure receiver/accumulator (7) provided in the circuit.
12. Arrangement for defrosting of a heat exchanger (evaporator) in a vapor compression system including, beyond the heat exchanger (evaporator) (3), at least a compressor (1), a second heat exchanger (condenser/heat rejecter) (2) and an expansion device (6) connected by conduits in an operable manner to form an integral closed circuit, where heat is added to the refrigerant by a heating device (10), ,
characterized in that, in the circuit, in connection with the expansion device (6) is provided a first bypass loop (23) with a first valve (16'), and that a pressure reducing device (6') is provided in a second bypass loop in conjunction with a second valve (16'') disposed after the heat exchanger (3) being defrosted, whereby the first valve (16') is open and the second valve (16'') is closed when defrosting takes place.
-
13. Method according to claim 12,
characterized in that the first valve (16') is provided in a bypass loop (20'), connecting the outlet of the compressor (1) to the inlet of the heat exchanger (evaporator) (3) that is to be defrosted.
14. Method according to claims 12 and 13,
characterized in that a low or intermediate pressure accumulator (7) provided in the circuit.
15. Arrangement according to claims 12-14,
characterized in that the heat exchangers (2, 3) are coupled in series.

16. Arrangement according to claims 12 - 14,,

c h a r a c t e r i z e d in that the heat exchangers (2, 3) are coupled in parallel.

17. Arrangement according to claim 16,

c h a r a c t e r i z e d in that a 3-way valve (22) is provided after the compressor to lead the refrigerant wholly or partly to the heat exchanger to be defrosted (3) through a bypass conduit loop (20).

18. Arrangement according to claims 12 - 16,

c h a r a c t e r i z e d in that a conduit loop (21) with an additional valve (16) is provided to bypass, wholly or partly the second heat exchanger (heat rejecter) (2).

19. Arrangement according to claims 12 - 15 the circuit being provided with an internal heat exchanger (9),

c h a r a c t e r i z e d in that a conduit loop (20) with an additional valve (16') is provided to bypass the internal heat exchanger (9).

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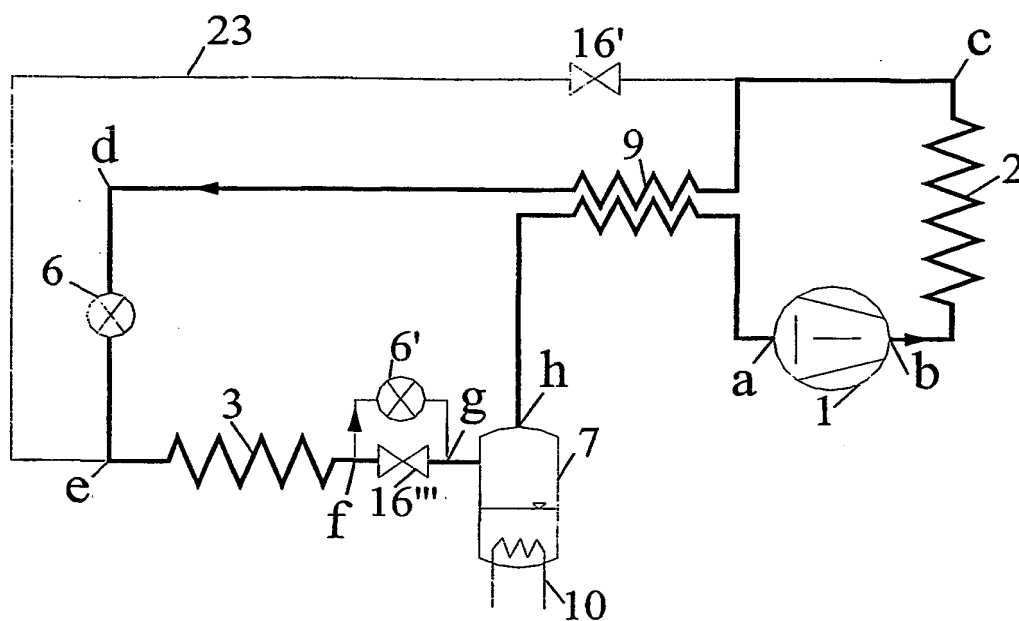


Fig. 1

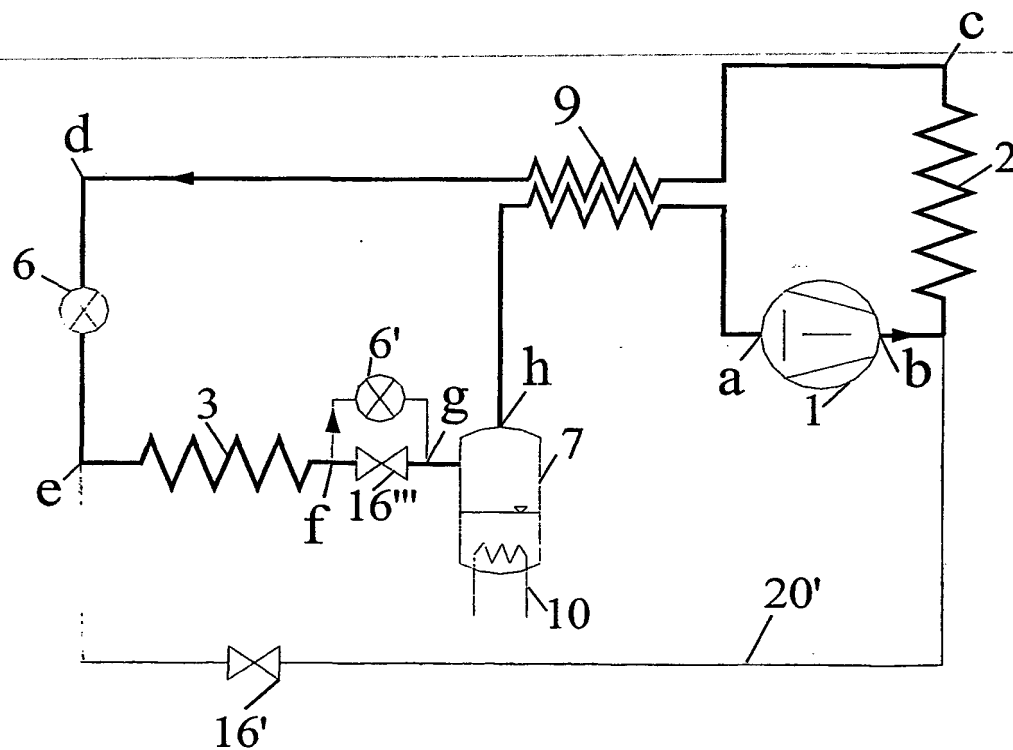


Fig. 2

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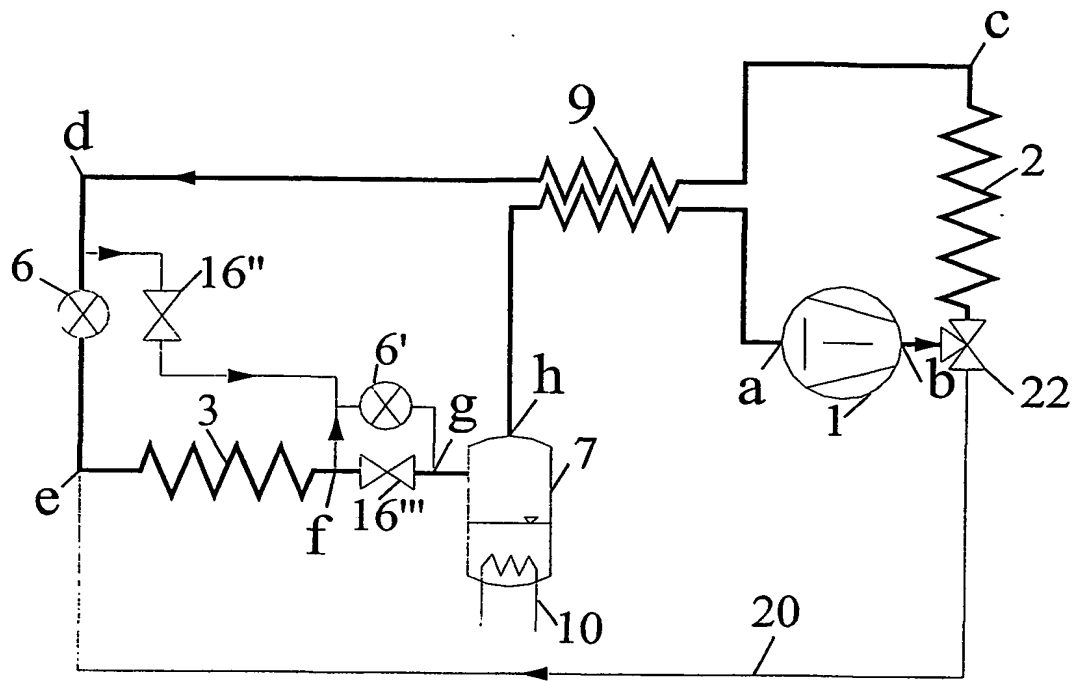


Fig. 3

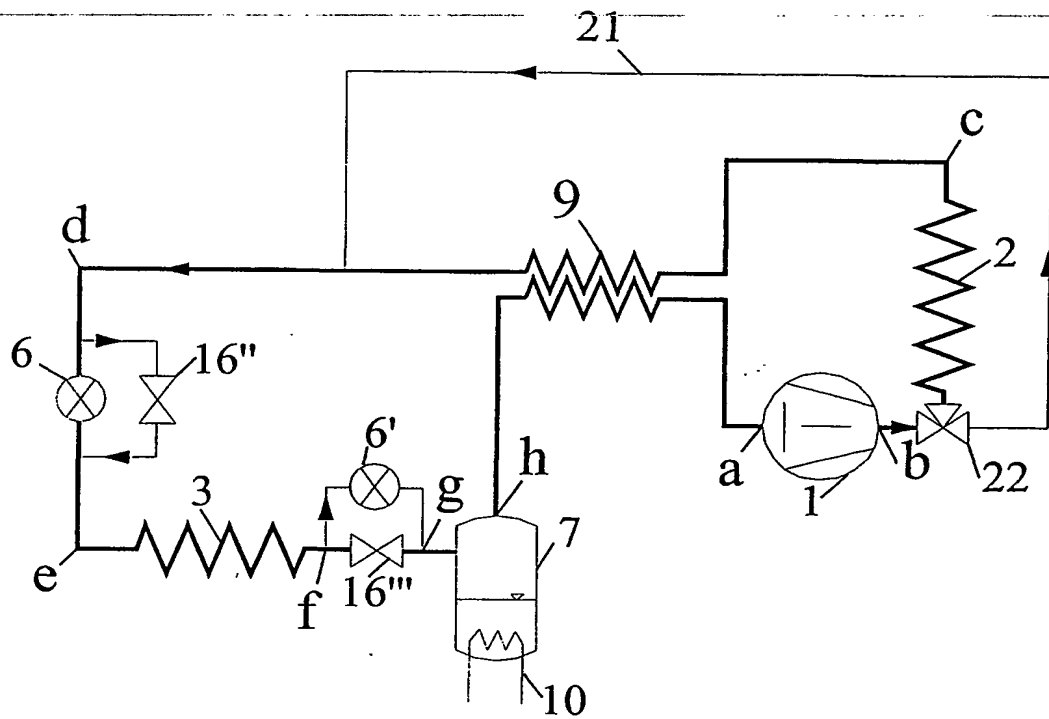


Fig. 4

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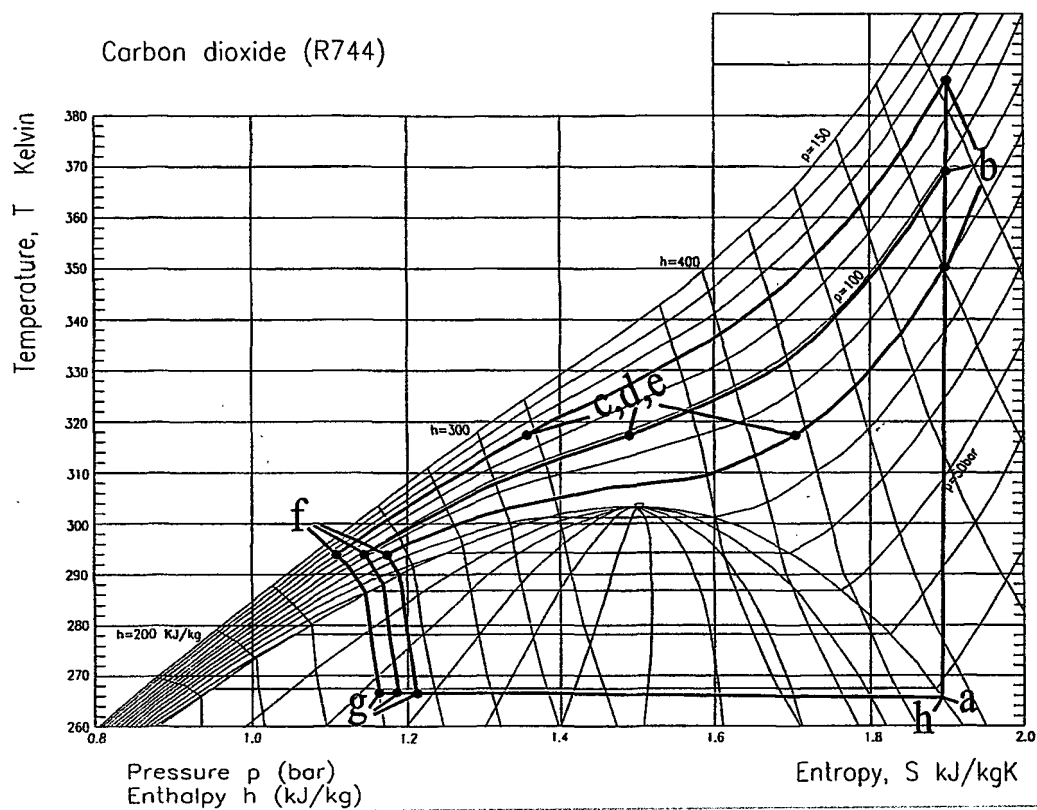


Fig. 5

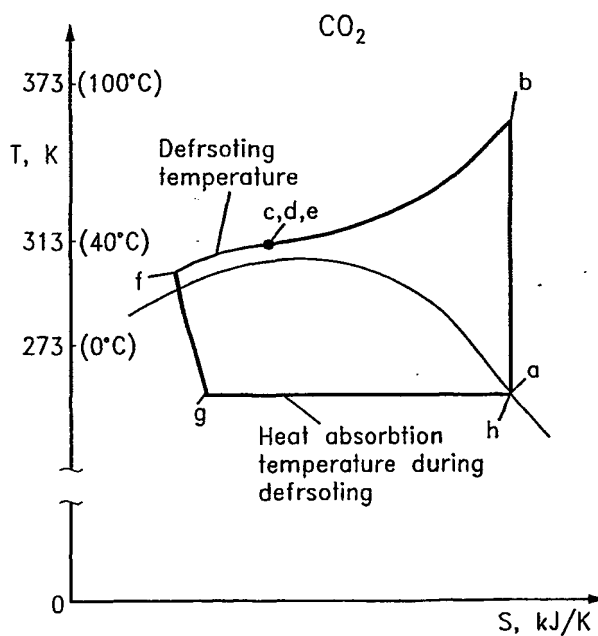
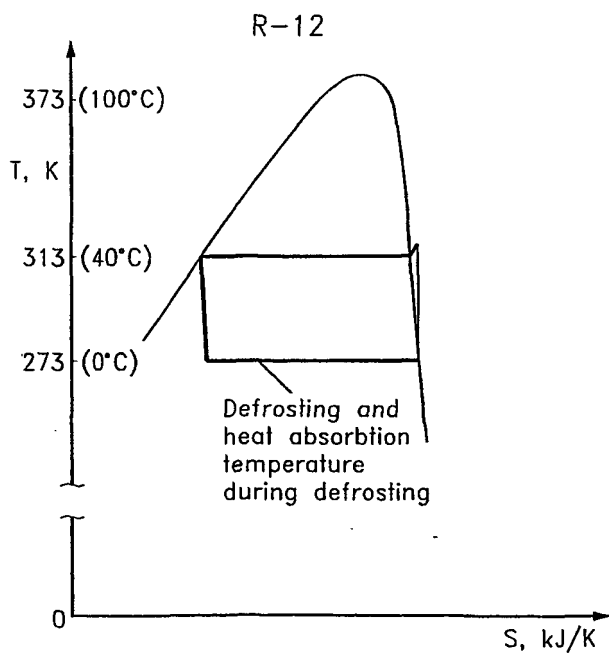


Fig. 6

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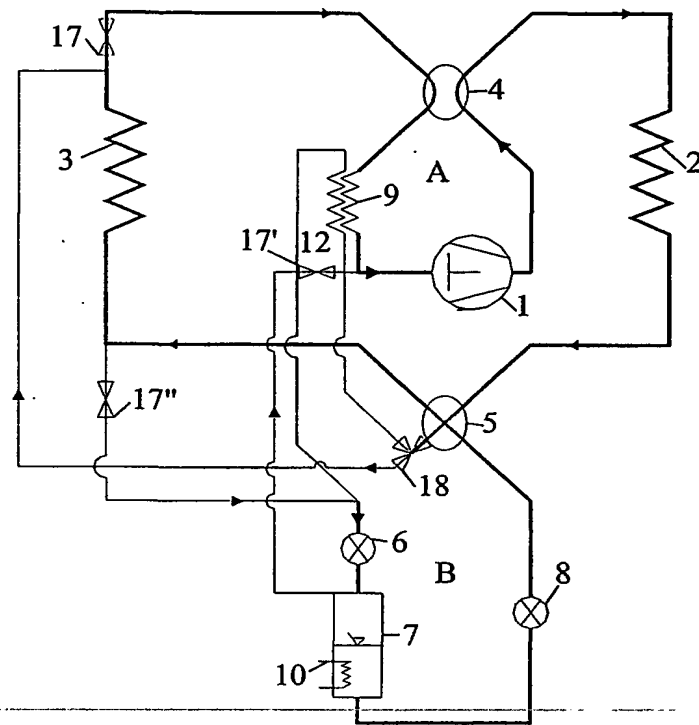


Fig. 7

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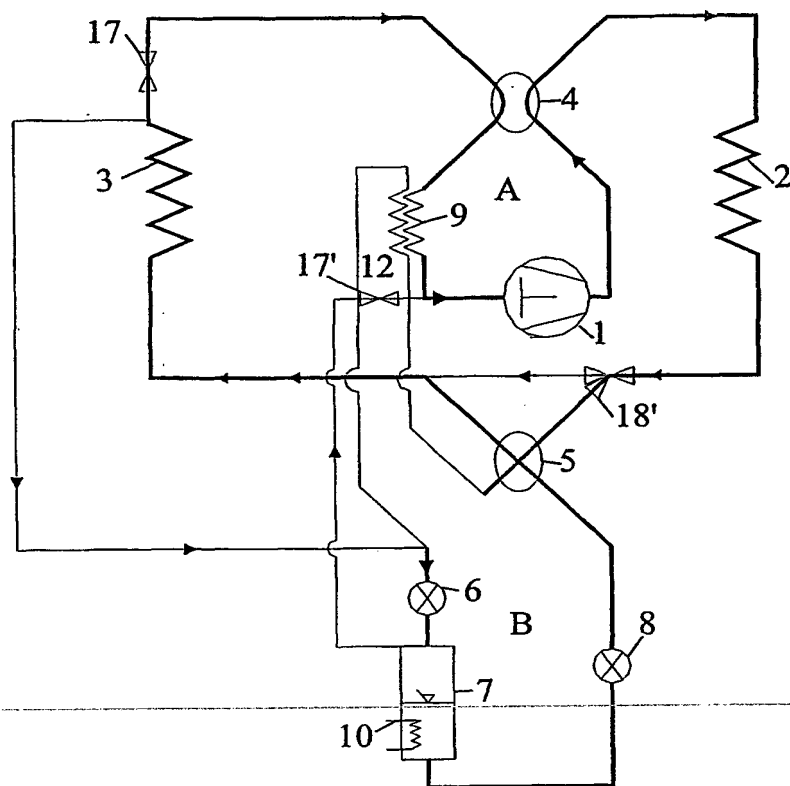


Fig. 8

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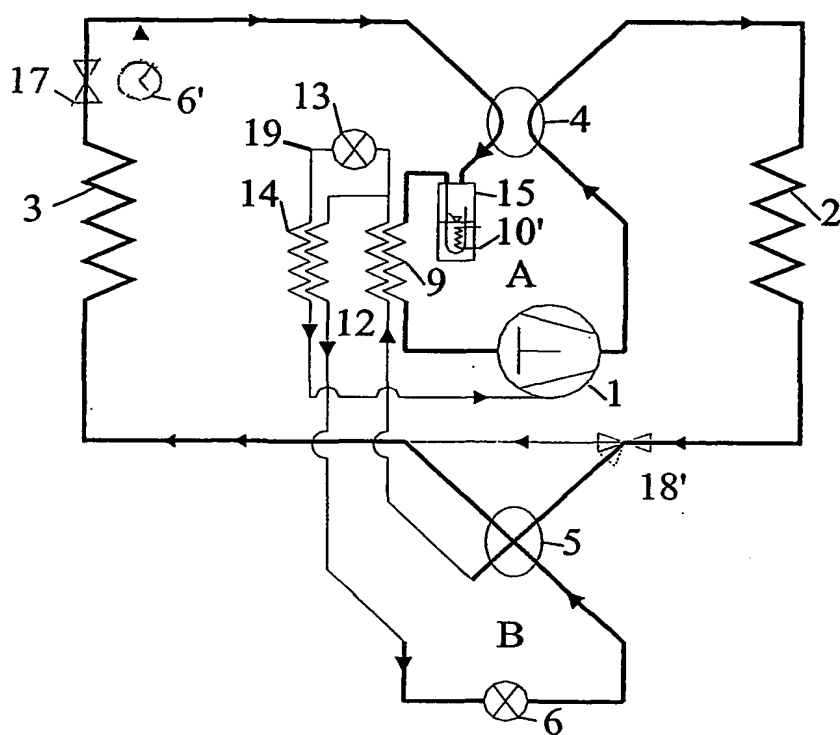


Fig. 9

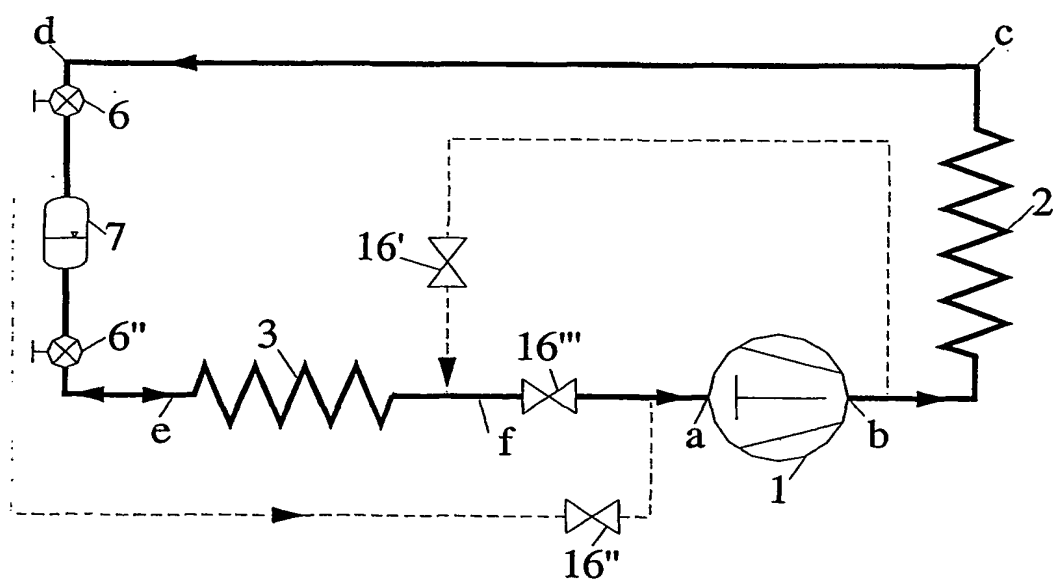


Fig. 10

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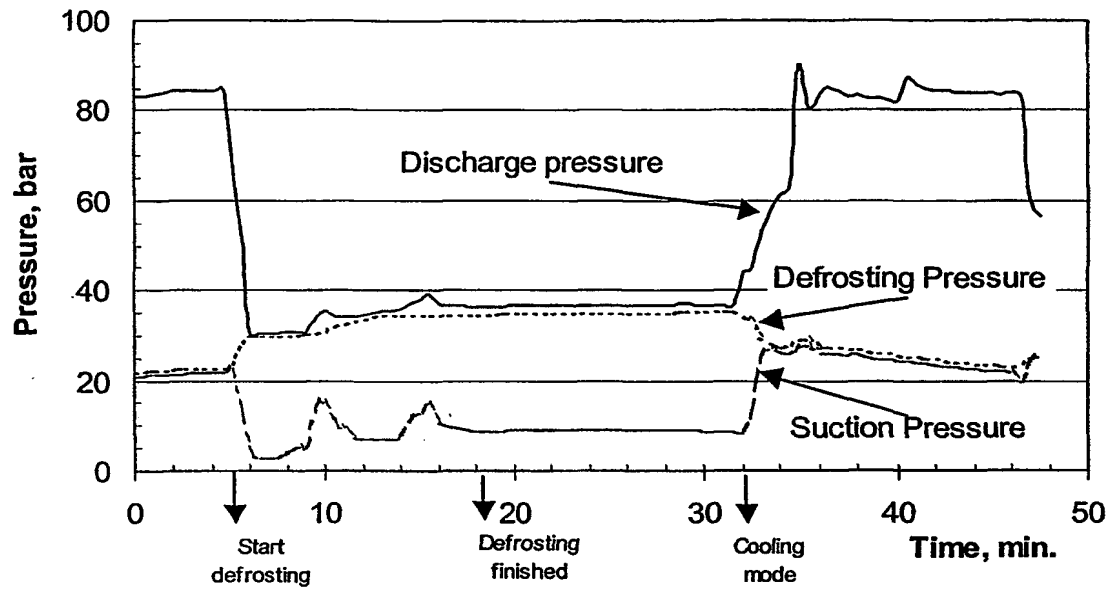


Fig. 11

INTERNATIONAL SEARCH REPORT

International application No.

PCT/NO 01/00354

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: F25B 47/02, F25B 9/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: F25B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5575158 A (VOGEL), 19 November 1996 (19.11.96), column 5, line 39 - column 6, line 59, figure 1 --	1,2,4-6,10, 12-13,15-16, 18
X	DE 2648554 A1 (MÜLLER, REINHARD), 10 November 1977 (10.11.77), page 7, figure 1 --	1-2,4,11-15, 18
X	DE 19517862 A1 (STIEBEL ELTRON GMBH & CO KG), 21 November 1996 (21.11.96), column 1, line 61 - column 2, line 54, figure 1 --	1-2,4,12,13

☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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A	US 4691527 A (IKEDA), 8 Sept 1987 (08.09.87), whole document --	1-19
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Information on patent family members

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